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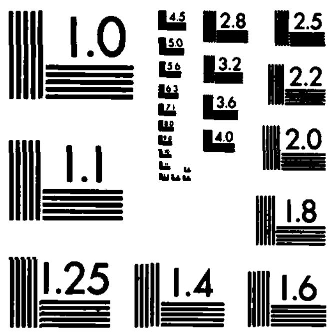

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A new design for a sea salt aerosol collector is described. It is specifically intended to collect aerosol samples from marine gas turbine air inlet ducts. Samples are deposited on 13 mm diameter filter membranes suitable for chloride determination using an ion selective electrode technique. The probe allows rapid removal and replacement of filters by ship's personnel. Loaded filters are transported to the measuring laboratory within a filter holder that obviates the need for handling the filters at the collecting site, thus minimizing contamination.

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CONTENTS

LIST OF FIGURES

Sea Salt Aerosol Collector for Marine Turbine Inlet Air Ducts

INTRODUCTION

Gas turbines power many of the Navy's newer classes of ships now entering service or under development. Their many advantages as marine propulsion units favor even more extensive use in the future. As the number of engines in service has increased and as service times lengthen, attention has focussed on the importance of knowing how much sea salt is ingested by the engine in the large volumes of air used. For example, at full power each of the four engines of a DD 963-class destroyer consumes about 50 m^3 or 60 kg of air per second.

Sea salt aerosol entering marine turbines can reduce engine performance, increase fuel costs, cause turbine blade corrosion and increase risks of catastrophic failure. Thus, filters are provided at inlet ducts to remove as much aerosol as feasible, and the Navy is exploring ways to measure how much actually enters the ducts and reaches the engines (Ruskin, et al., 1978 and 1981, Lepple, et al., 1980 and 1981) and how aerosols impact ship operation (Lepple, et al., 1982).

Sea salt aerosol concentrations within the ducts range from about 5×10^{-5} to 5×10^{-2} ppm (0.06 to 60 micrograms/m^3). An aerosol measuring technique based on an electrochemical sensor system appears promising. Aerosol samples can be collected on

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filters and total sea salt estimated using an ion selective electrode to measure chloride concentration by pressing the electrode against the filter. Samples as small as 10 microliters can be precisely determined using confined spot test paper (S & S Yagoda, No. 211-Y, or its equivalent) as the sample container (Orion, 1981). The essence of the proposed system is that:

1. Samples are highly concentrated on the filter.
2. Samples are in a form well-suited for electrode measurement.
3. Individual filters can be removed and replaced quickly and easily by ship's personnel.
4. The measurement itself is simple enough that eventually it may be done by ship's personnel, given a properly engineered shipboard device. If the number of measurements needed is large enough, a fully automatic device based on these principles appears to be feasible.

The first requirement is a probe designed to penetrate inlet duct walls and collect aerosol samples of suitable size and configuration. The probe is designed to allow easy collection of samples particularly suited to the proposed measuring technique This report describes the design of the prototype probe.

PROBE DESIGN

The probe is a 5.08 cm (2") diameter cylinder, approximately 60 cm (24") in length, designed to penetrate the duct wall

through a 2" PVC ball valve. A series of photographs (Figs. 1-3) shows the complete probe in progressive stages of disassembly. Detailed design information is given in Figs. 4-9. Fig. 4 is a partially exploded perspective view of the probe showing the arrangement and nomenclature of the components. In this prototype, the body (Fig. 5) is constructed of polycarbonate plastic (Lexan). Except where otherwise noted, the other parts are nylon.

A conical plug, shown in Fig. 6, fits into the end of the probe body to reduce turbulence and edge effects. Both ends of the slot in the body are blocked by probe head supports (Fig. 7) providing low friction bearing surfaces which hold the probe head in position. The probe head (Fig. 8) is the working part of the probe. It consists of an approximately hemicylindrical block machined to accept a 13 mm Swinnex Filter Unit (polypropylene, with silicone gasket, Millipore No. SX 00 13 00). The inlet is an expanding cone (43.6° half angle) with a 0.737 cm (0.29") diameter orifice. An "O" ring (Buna N, Parker No. 2-13), visible in the bottom of the probe head cavity in Fig. 3c, provides a vacuum tight seal against the filter unit. Pressure against this "O" ring is maintained by the filter retainer ring (Fig. 8). This retainer ring also makes a sliding "O" ring seal (Buna N, Parker No. 2-14) with the vacuum mating piece protruding from the probe tailpiece (Fig. 9). The tailpiece provides a Swagelok connection for a vacuum hose (1/4" OD x 0.040" Wall, PVC, Samuel Moore "P" tubing) which terminates in a quick disconnect Swagelok coupling at the base of the probe.

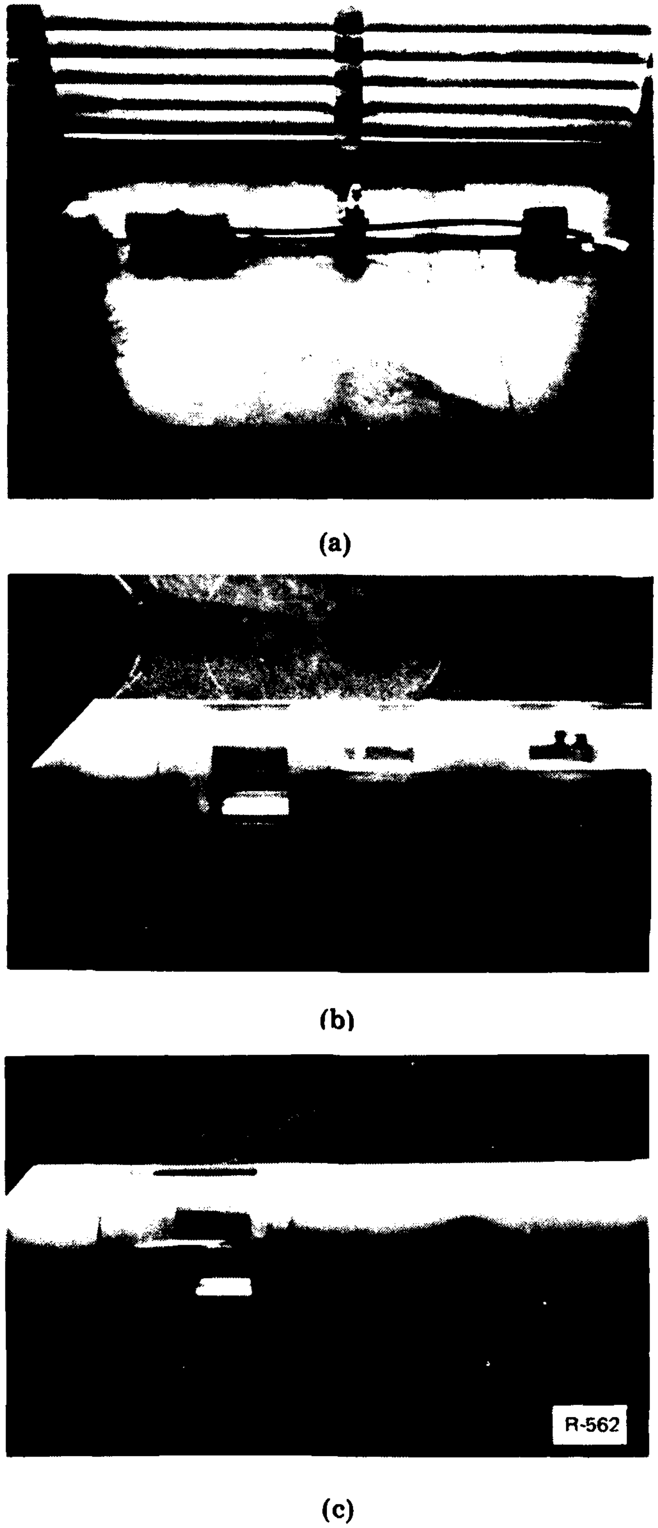
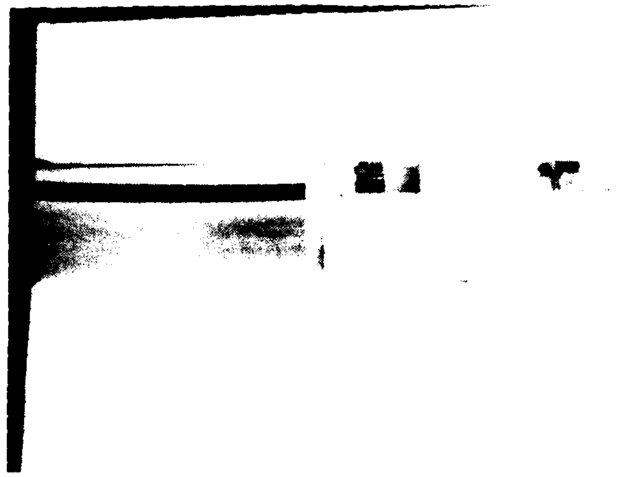


Figure 1. (a) Assembled probe with probe head at left, (b) detail of probe head mounting, (c) probe head from upstream side showing orifice for aerosol entry and shadow of inner sealing O-ring.



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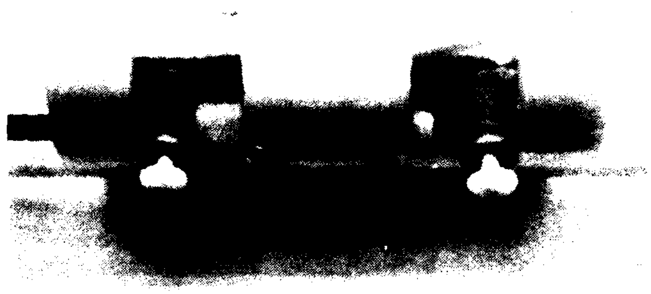

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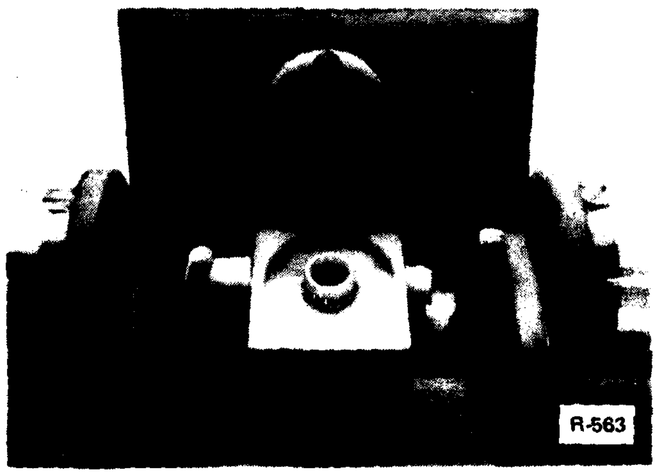

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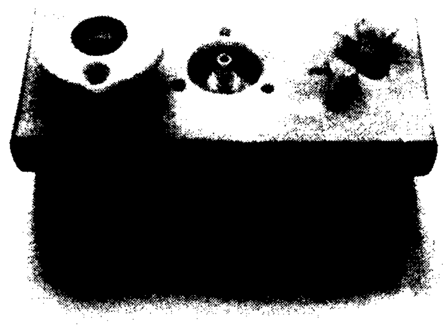
Figure 2. (a) Probe head mounting, (b) downstream side of probe head (the probe tailpiece) with retaining bolts partially removed, (c) probe head and filter retainer ring lifted off of probe tailpiece.



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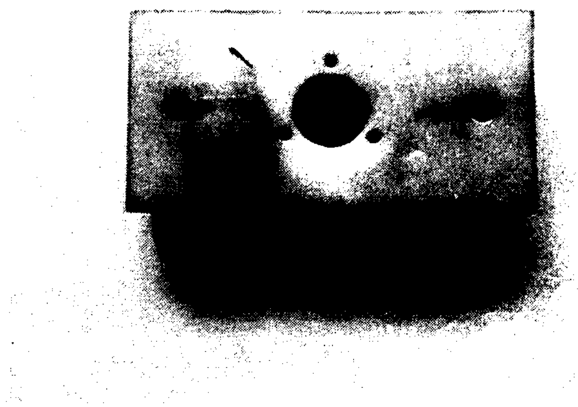

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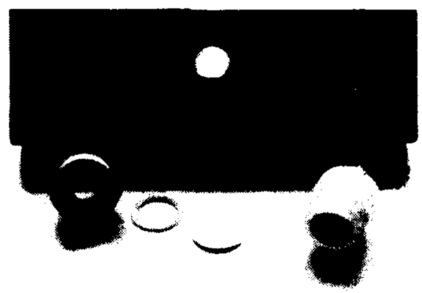

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Figure 3. (a) Probe head with filter retainer ring removed, (b) probe head with Millipore filter holder removed, (c) filter removed from Millipore filter holder.

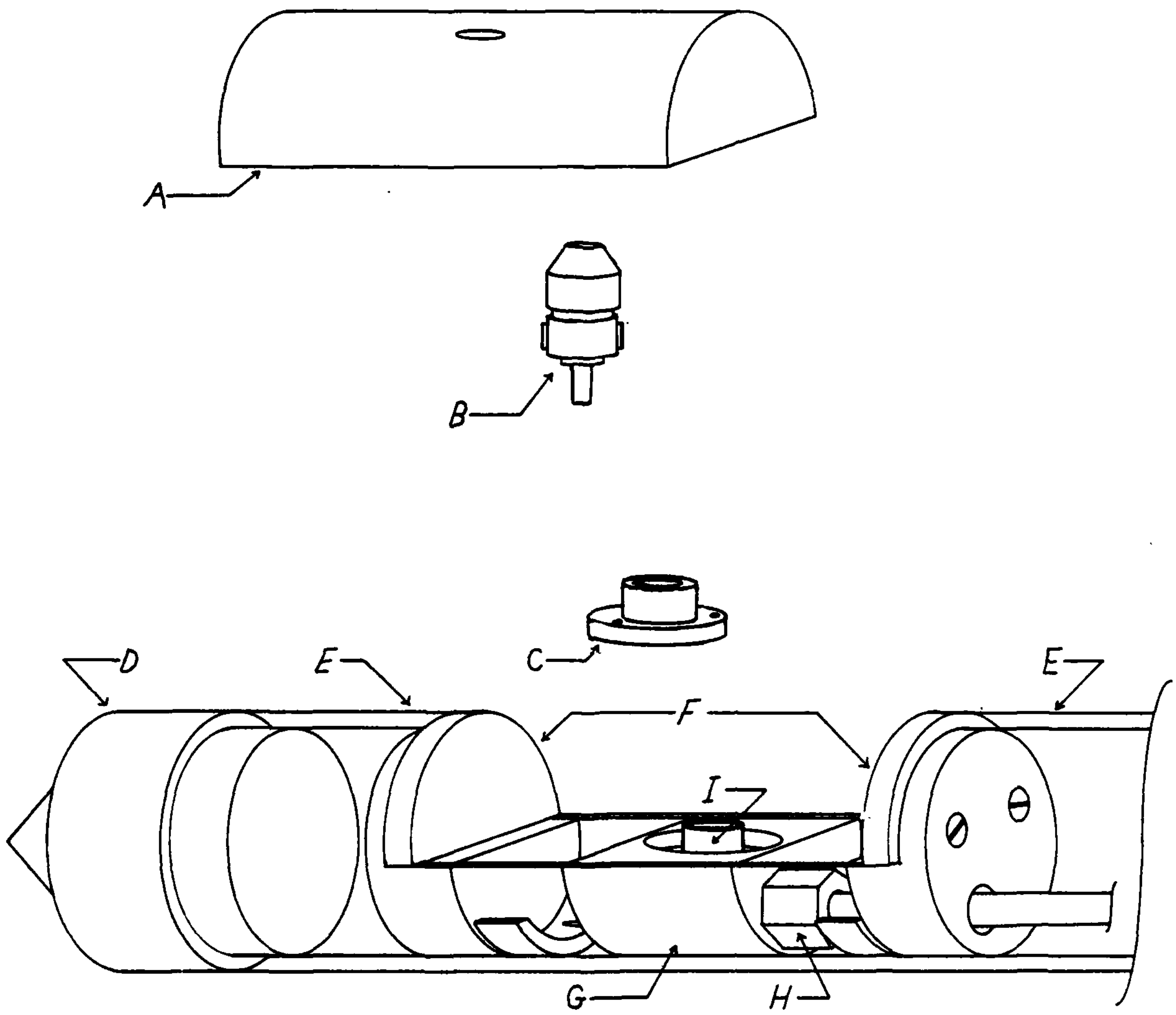

Figure 4. Perspective view of the aerosol sampling probe. The nomenclature is as follows: (A) probe head, (B) Millipore filter holder, (C) filter retainer ring, (D) probe end plug, (E) probe body, (F) probe head supports, (G) probe tailpiece, (H) Swagelok connector for vacuum hose, (I) vacuum mating piece.

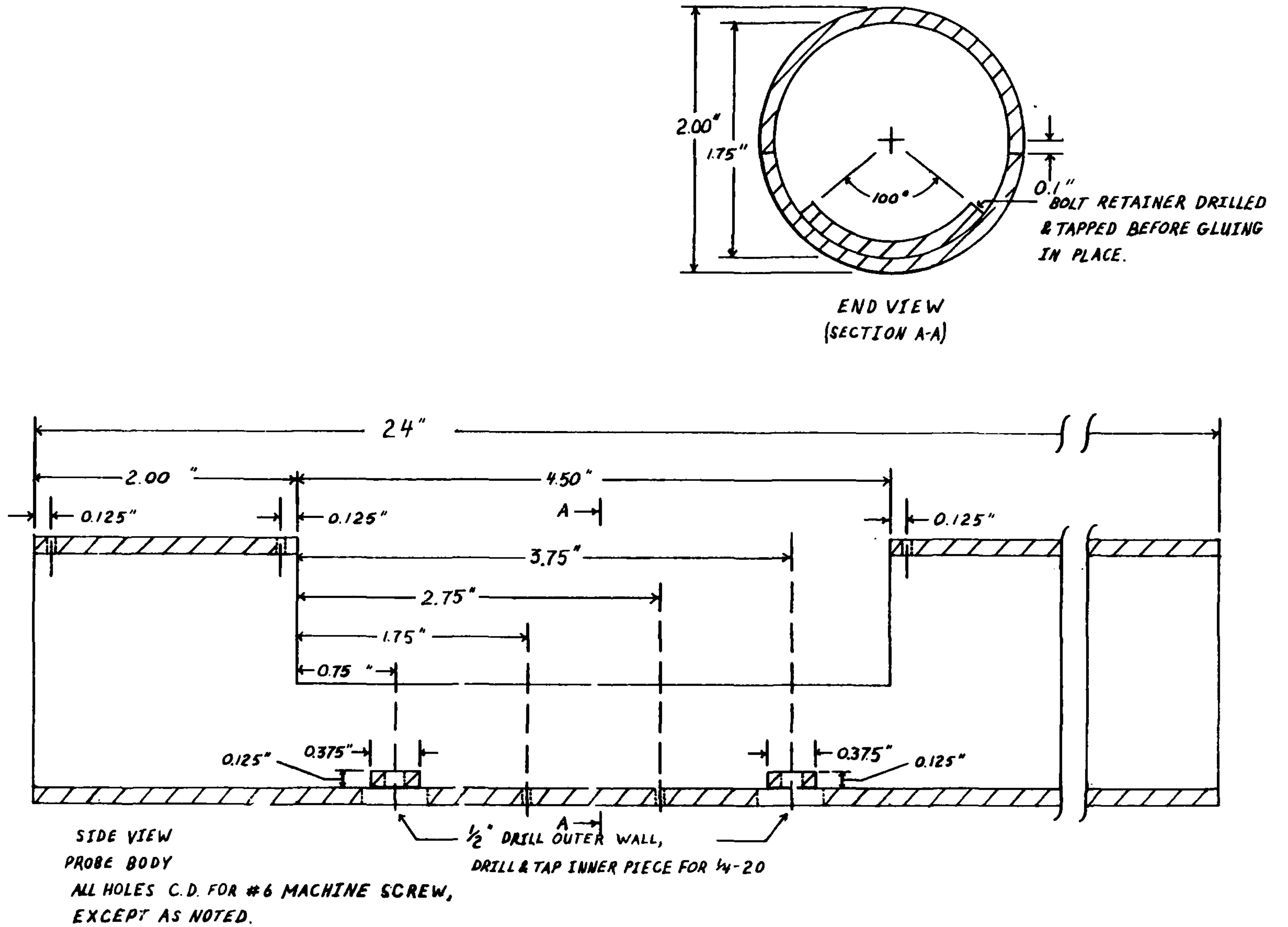

Figure 5. Engineering drawing for the probe body.

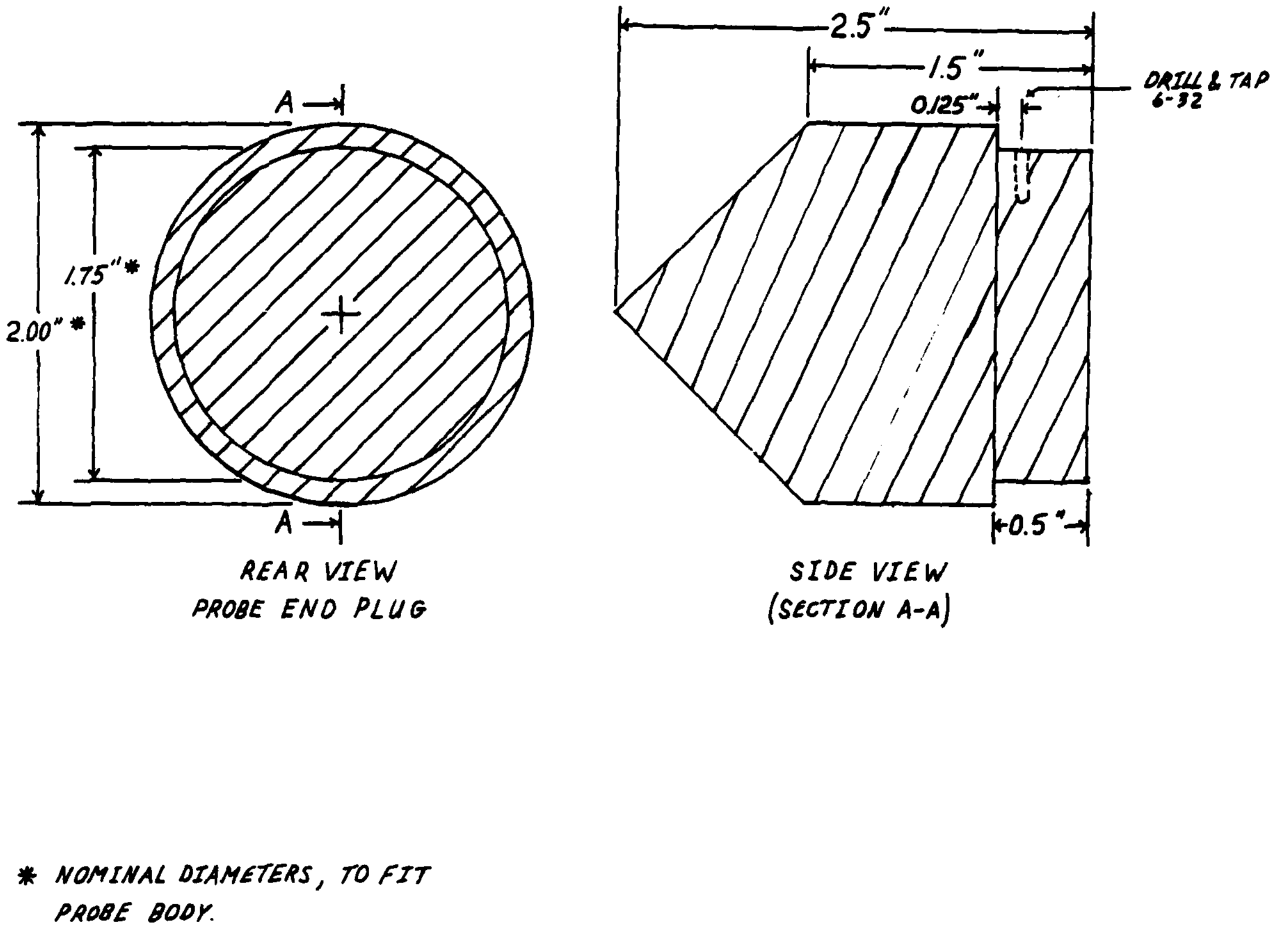

Figure 6. Engineering drawing for the probe end plug.

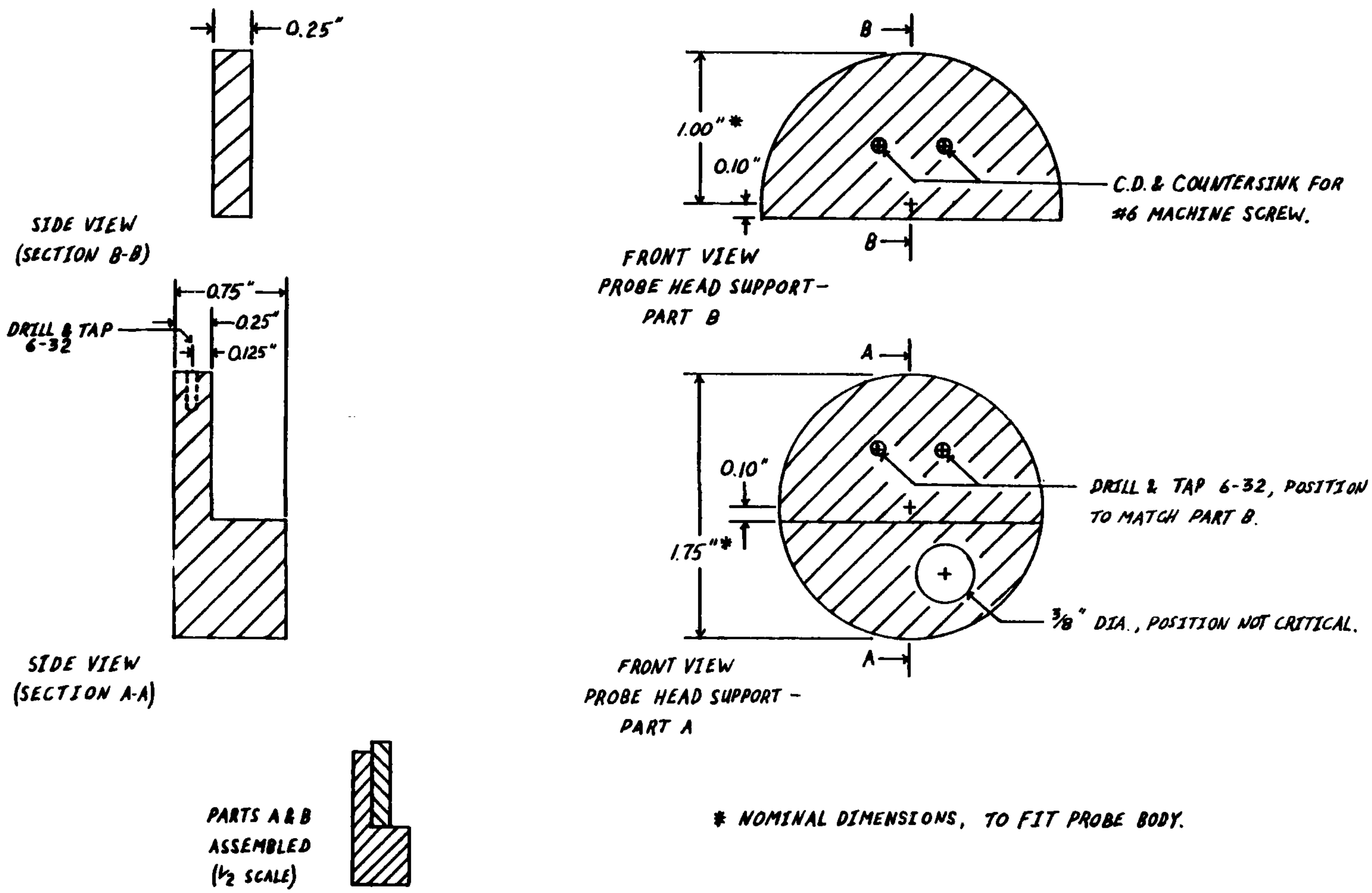

Figure 7. Engineering drawings for the probe head supports.

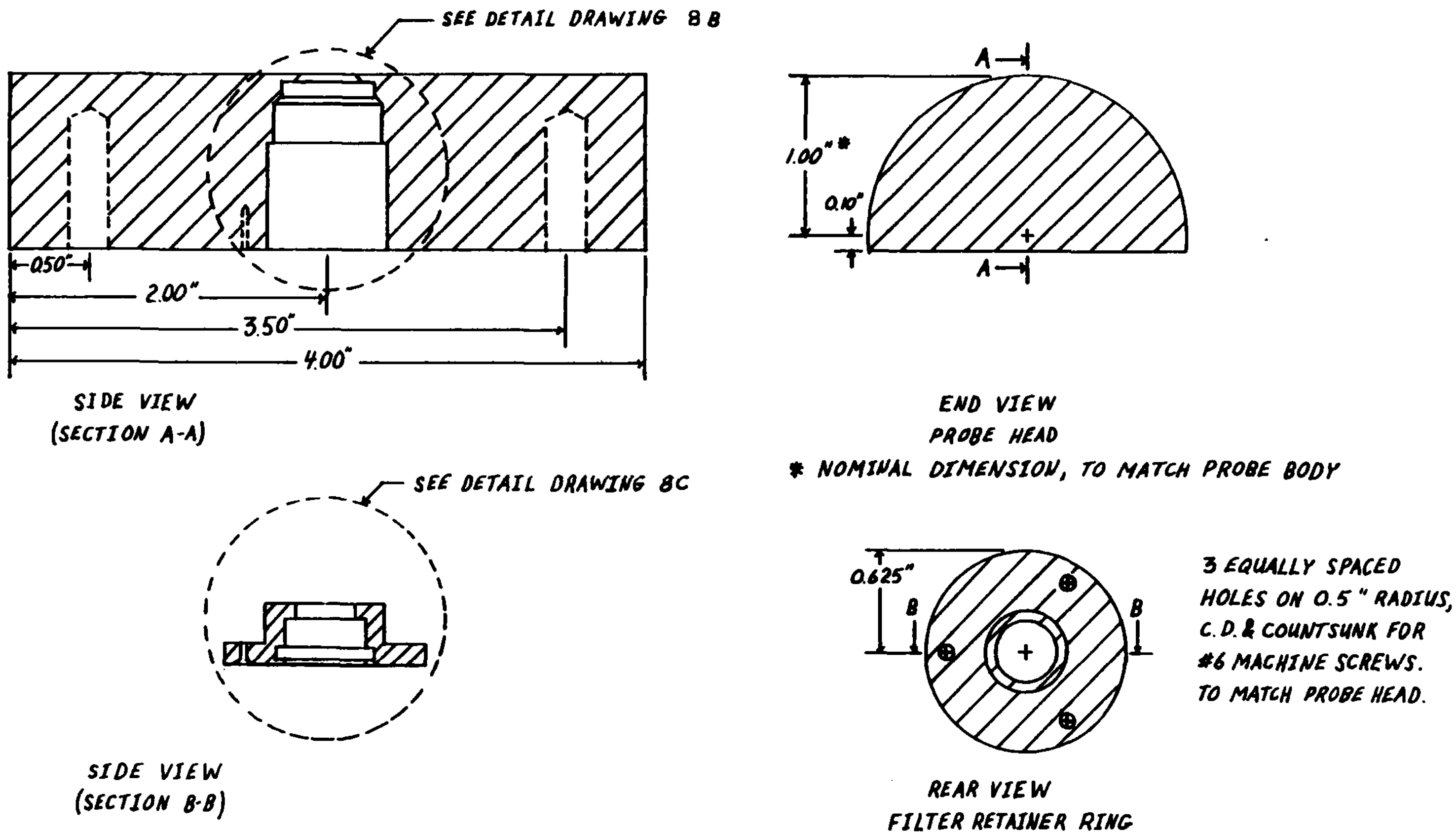

Figure 8a. Engineering drawings of the probe head and filter retainer ring.

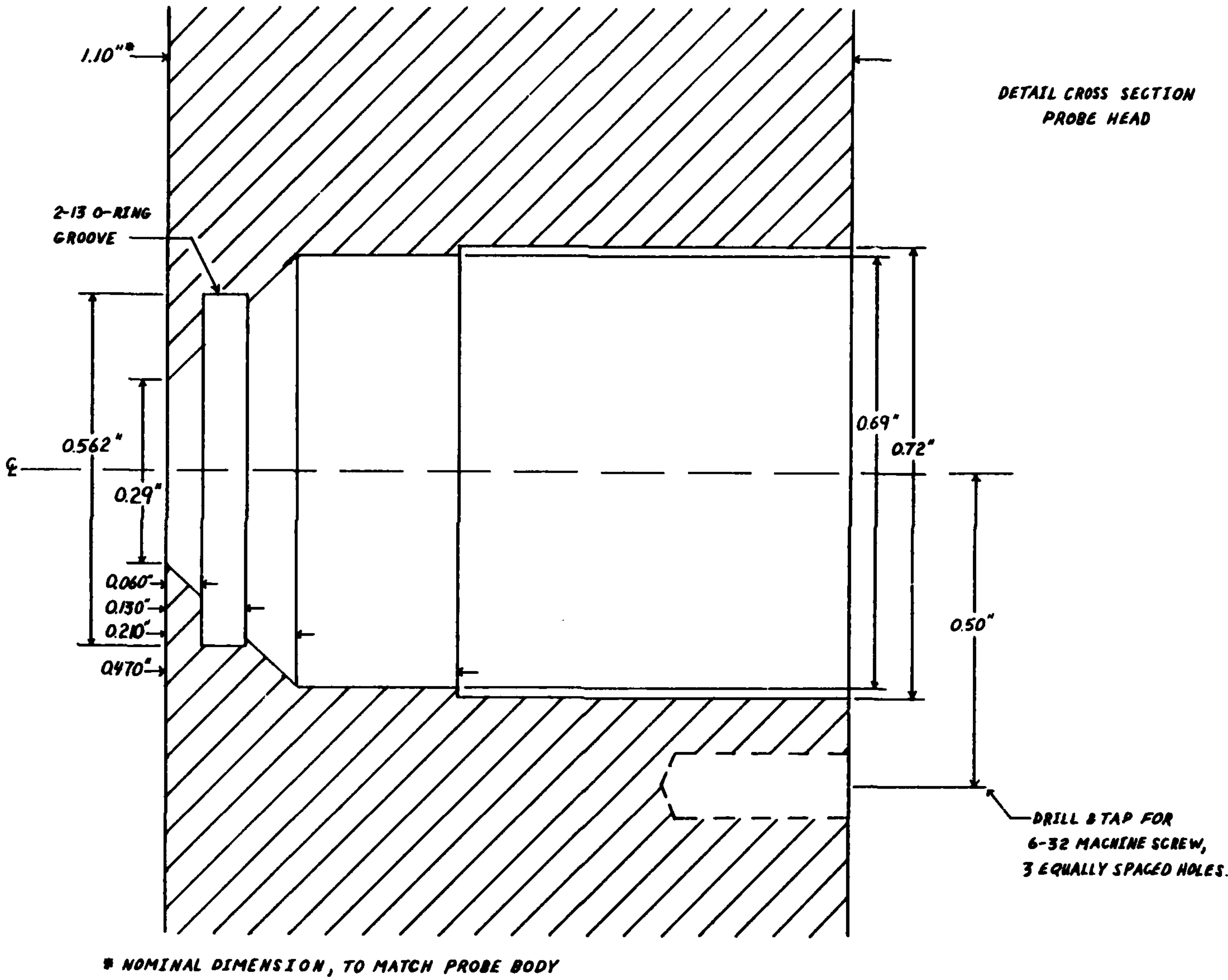

Figure 8b. Detail of probe head.

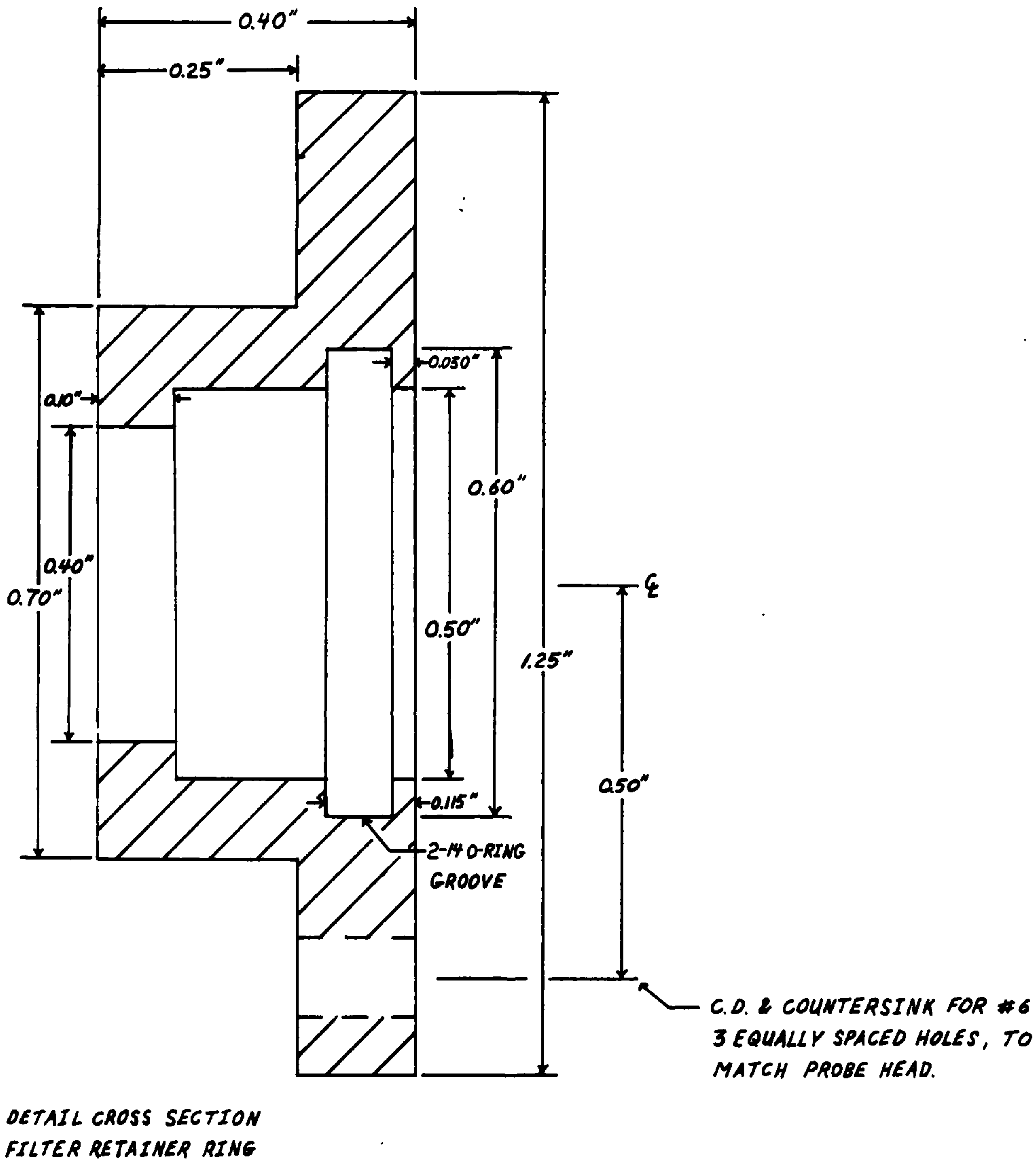

Figure 8c. Detail of filter retainer ring.

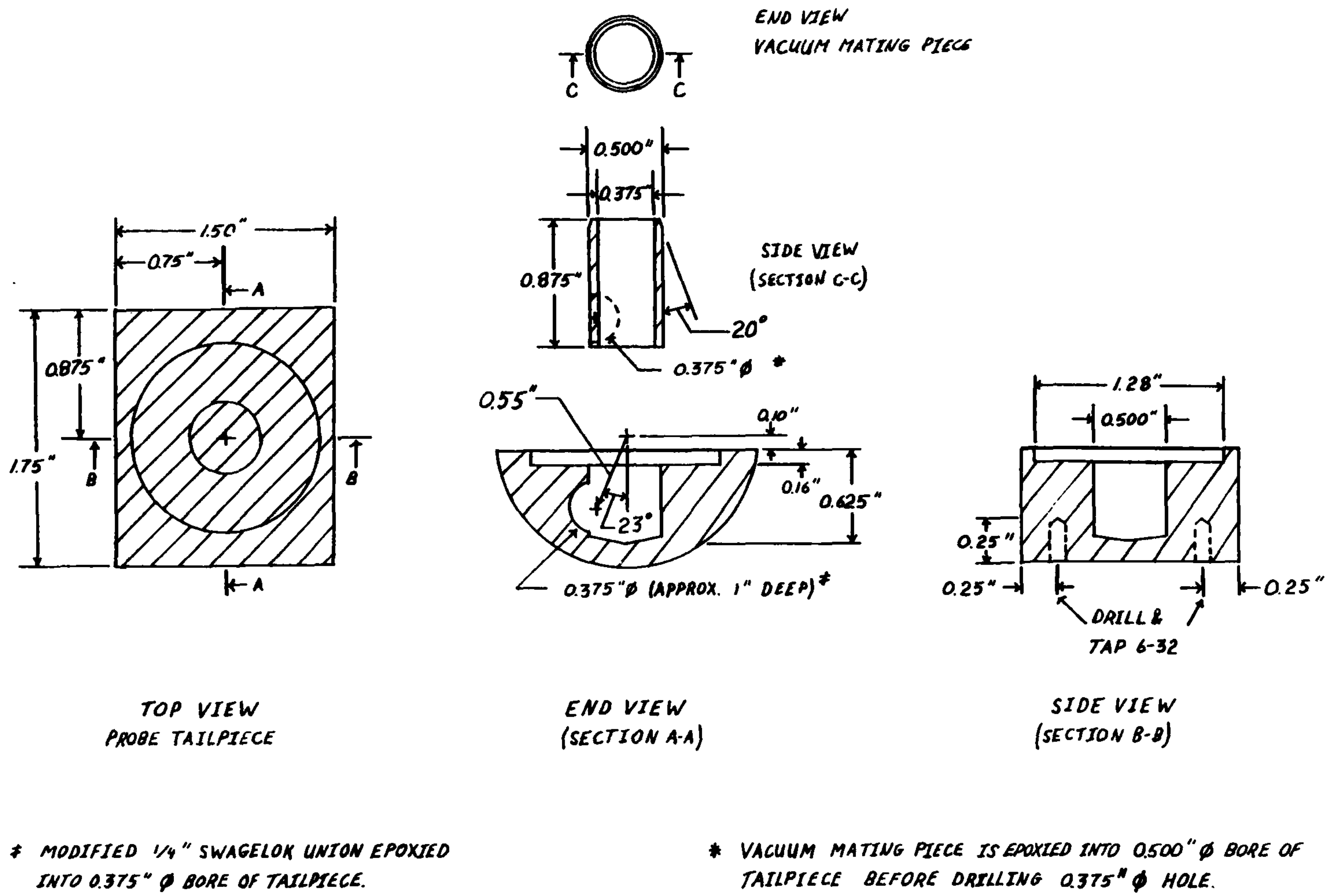

Figure 9. Engineering drawings of the probe tailpiece and vacuum mating piece. The 1/4" Swagelok union was modified and attached as follows: (1) the hexagonal portion of the body was turned to 0.375" diameter, (2) the unthreaded portion was cut to 0.5" length, and (3) the cylinder was secured in the tailpiece with epoxy.

The filter is held within a Swinnex filter unit which was modified by removing the Luer-Lok inlet and drilling the orifice to 0.556 cm (7/32") diameter. In addition, the "ears" on the forward half of the filter unit were removed and the lettering was polished off of the conical surface. The latter is necessary in order to allow a good vacuum seal. The filter unit was chosen so that filters can be exchanged while still contained within the closed Swinnex unit. The filter unit is shown assembled and disassembled in Figs. 3b and 3c, respectively.

This design allows field replacement of a filter by ship's personnel with minimal chance of contamination. The entire Swinnex unit can be removed from the probe head, stored in a plastic bag, and either taken to a laboratory aboard ship or sent to a contractor laboratory. Actual opening of the filter unit and removal of the filter will be done in the laboratory just prior to measurement.

DISCUSSION

Initial tests have suggested several areas for improvement of the probe design, most notably in the method of removal and installation of the Swinnex filter holder. Since this operation will be carried out frequently, it is important that it be as simple as possible.

Currently, when the probe is withdrawn from a duct, two captive screws must be disengaged before the probe head can be lifted off. After taking out three machine screws, the filter retainer ring may be removed and the filter unit lifted out. A

fresh filter unit is replaced in the probe which is reassembled and reinserted into the duct. The vacuum seals are automatically made. This procedure is somewhat slow and tedious and there is a significant risk of losing some of the parts.

A useful modification would replace the captive screws with some form of spring-loaded twist-lock device. The three screws holding the filter retainer ring in place could be eliminated by replacement of the existing ring with a threaded version. This would be screwed into place using a wrench. We believe that these changes would significantly simplify the process of exchanging filter holders.

The probe is only a holder for the filter and a conduit to transport air through the filter. A pumping system is needed to draw air through the probe. A primary requirement for correct sampling is that the pumping must be isokinetic. This implies a requirement for measurement of the air flow rate within the duct and for adjustment of the pumping speed as appropriate. Furthermore, the total volume of air sampled must be known so that the absolute aerosol concentrations may be determined.

At least one commercially available sampling pump (Kurz Instruments, Inc.) has provision for self-regulation of pumping speed based on air flow measurements from a remote sensor. The sensor should be incorporated into the probe to ensure accurate measurement of the local flow rate. A separate recorder would still be required to monitor air volume.

Looking further into the future, we envision that there will be a need for increased control and data-processing capability

built into the system. This is especially true if a fully automated device is desired. At that point, it would probably become practical to replace both the pump controller and the air volume recorder with a microprocessor-based system controller/data logger. This single unit would provide both pump control and continuous monitoring of sampling rate. It also lends itself to easy expansion as new capabilities are added.

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